FM 85: Poster: Enabling Technologies: Cavity QED

Time: Thursday 16:30–18:30 Location: Tents

FM 85.1 Thu 16:30 Tents

Cavity-enhanced spectroscopy of a few-ion ensemble in $Eu^{3+} : Y_2O_3$ — Bernardo Casabone[1,2], Julia Benedikter[2,3,4], Thomas Hümmer[2,3], Franziska Oehl[3], Karmel De Oliviera Lima[5], Theodor W. Hänsch[2,3], Alban Ferrier[5,6], Philippe Goldner[5,6], Hughes De Riedmatten[1,7], •Timon Eichhorn[4], Kelvin Chung[4], and David Hunger[4] — [1]ICFO-Institut de Ciencies Fotoniques — [2]Max-Planck-Institut für Quantenoptik — [3]Fakultät für Physik, Ludwig-Maximilians-Universität — [4]Karlsruher Institut für Technologie — [5]Université PSL, Chimie ParisTech, CNRS — [6]Sorbonne Université — [7]ICREA-Institució Catalana de Recerca i Estudis Avançats

A promising approach for realizing scalable quantum registers lies in the efficient optical addressing of solid state quantum memories. Within the EU Quantum Flagship project SQUARE we tackle this problem by coupling the flourescence of Eu ions in Y_2O_3 nanoparticles (NPs) to a high-finesse fiber-based Fabry-Pérot microcavity. As a first step towards efficient readout of single rare earth ions, we present cavity-enhanced spectroscopy measurements of a few europium-ions as published in New J. Phys. **20** (2018) 095006. In particular, we focus on the coherent transition $^5D_0 -^7 F_0$ of Eu^{3+} that has been shown to have narrow optical linewidth in the order of 100 kHz. We determined the number of ions in a NP and observed an increased fluorescence count rate in agreement with the Purcell enhancement of the cavity. An inhomogeneous linewidth of 22 GHz, which is close to bulk value, indicates high crystal quality of the NPs.

FM 85.2 Thu 16:30 Tents

Towards a coherent spin photon interface for quantum repeaters using NV centers in diamond — •Maximilian Pallmann[1], Rainer Stöhr[2], Eugen Vasilenko[1], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Universität Stuttgart

Building a long distance quantum network is one of the big challenges in the field of quantum communication, which requires the development of a quantum repeater. A crucial component of this is an efficient, coherent spin photon interface, and coupling single Nitrogen Vacancy centers to a microcavity is a promising approach therefor. In our experiment, we integrate a diamond membrane to an open access fiber-based Fabry-Perot microcavity to increase the weak emission into the Zero Phonon Line (ZPL) of NV centers. Simulations predict the feasibility of a strong enhancement of the ZPL emission efficiency, reaching values of up to 80%. We present a spatially resolved characterization of a coupled cavity-membrane device and report on the current status of the experiment.

FM 85.3 Thu 16:30 Tents

Quantum Fourier Transform in Oscillating Modes — •Qi-Ming Chen[1,2], Frank Deppe[1,2,3], Stefan Pogorzalek[1,2], Michael Renger[1,2], Kirill G. Fedorov[1,2], Matti Partanen[1,2], Achim Marx[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 Munich, Germany

Quantum Fourier transform (QFT) is the key ingredient for many quantum algorithms. Typical applications of QFT, such as phase estimation, require a considerable number of qubits as well as a square number of quantum gates to form a Hilbert space large enough for generating high-precision results. Even though qubit recycling can be used to realize semi-classical FT with a single ancilla qubit in problems related to phase estimation, one pays the price of repeated measurements and feedforward throughout the process. In this work, we map the qubit state onto an oscillating mode with an infinite-dimensional Hilbert space, and implement QFT by means of two coupled oscillating modes with cross-Kerr interaction. This method enables high-dimensional fully-quantum FT with state-of-the-art superconducting quantum circuits.

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FM 85.4 Thu 16:30 Tents

Multimode cavity QED description of photonic Bose-Einstein condensation — •David Steinbrecht[1], Robert Bennett[1,2], and Stefan Yoshi Buhmann[1,2] — [1]University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), Germany

Photonic Bose–Einstein condensation is a novel quantum state of light that arises when a laser-driven ensemble of dye molecules thermalises with light inside a cavity [1]. We are developing a first-principles description of the spatiotemporal structure of the phenomenon on the basis of multimode cavity QED. In our model, the molecule–light interactions are described in an open systems approach that quantifies spontaneous decay, cavity losses and intramolecular channels. The spatial mode structure is determined in terms of the electromagnetic Green's tensor [2].

[1] J. Klaers, J. Schmitt, F. Vewinger and M. Weitz, Nature **468**, 545 (2010).

[2] S. Esfandiarpour, H. Safari, R. Bennett, S. Y. Buhmann, J. Phys. B **51**, 094004 (2018).

FM 85.5 Thu 16:30 Tents

An atom-cavity system for high-bandwidth quantum networks — •Maximilian Ammenwerth, Lukas Ahlheit, Wolfgang Alt, Tobias Macha, Pooja Malik, Deepak Pandey, Hannes Pfeifer, Eduardo Urunuela, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115, Bonn, Germany

Miniaturized fiber Fabry-Pérot cavities are robust and integrable atom-light interfaces with emerging applications in fiber-based quantum networks. Their small mode volume allows for the combination of strong light-matter coupling and high input bandwidth [1]. For these *open* resonators, the well-known technique of cavity cooling is not easily accessible. As an alternative, we present degenerate Raman Sideband Cooling, which makes use of Raman transitions driven by the atom-confining dipole trap beams.

We demonstrate the storage of short light pulses by employing a single rubidium atom coupled to the resonator and an assisting control laser [2]. The optimal control pulse is found from a numerical optimisation based on simulating the system dynamics via the Lindblad master equation. A storage efficiency of $(8.2 \pm 0.9)\%$ is found for a coherent wavepacket with a full width at half maximum of 5 ns, a duration well below the atomic decay time. The measured efficiency is in good agreement with the numerical simulation encouraging *hybrid experiments* with semiconductor quantum dots as light sources.

[1] PRL 121, 173603 (2018)
[2] arXiv:1903.10922 (2019)

FM 85.6 Thu 16:30 Tents

A rigid fiber Fabry Pêrot cavity for spectroscopic applications — •Carlos Saavedra, Madhavakkannan Saravanan, Wolfgang Alt, Deepak Pandey, Hannes Pfeifer, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115, Bonn, Germany

Optical fiber cavities present a versatile system to confine light in small mode volumes for a broad range of applications, such as cavity QED [1], frequency filtering or spectroscopic applications. We present a monolithic fiber cavity assembly, which offers high passive stability in a compact mount. We outline the general procedure of our rigid cavity fabrication and characterization process [2]. We demonstrate active stabilizion of the length of the cavity using the Pound-Drever-Hall locking technique.

[1] New J. Phys. 12, 065038, (2010)
[2] Appl. Phys. B 122:47, (2016)

FM 85.7 Thu 16:30 Tents

Heteroepitaxial growth of GaP membrane structures on Silicon — •Muhammad Shaharukh[1], Paul Mertin[2], Friedhard Römer[2], Bernd Witzigmann[2], Johann Peter Reithmaier[1], and Mohamed Benyoucef[1] — [1]Institute of Nanostructure Technology and Analytics (INA),CINSaT,University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Computational Electronics and Photonics (CEP), CINSaT, University of Kassel, Germany

The growth of III-V materials on Si is quite challenging due to the lattice mismatch and incompatible thermal expansion coefficients, which leads to a high density of dislocations. Due to the low lattice mismatch, GaP has been shown to overcome these obstacles. GaAs and Si- based photonic crystal (PhC) cavity prevents the use of emitters such as molecules that typically have resonances at visible wavelengths. GaP-based PhC cavity is one of the possible candidates for coupled PhC cavity-molecule systems to generate identical single-emitters for potential applications in scalable solid-state quantum systems.

Here, we report on the growth of GaP on Si substrates as well as GaP-based membrane structures using molecular beam epitaxy. The effects of different growth parameters on the formation of GaP structure where nucleation layer acts as a virtual substrate are investigated. The design and fabrication of GaP-based PhC cavity structures are also discussed. The optical properties of the grown structures are examined by photoluminescence spectroscopy.

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FM 85.8 Thu 16:30 Tents

Natural cavities with huge Purcell factors in gold nano sponges — Felix Schwarz[1], Sebastian Bohm[1], •Erich Runge[1], Dong Wang[1], Peter Schaaf[1], Jinhui Zhong[2], Juemin Yi[2], and Christoph Lienau[2] — [1]TU Ilmenau — [2]Universität Oldenburg

Metallurgically produced porous gold nanoparticles, so-called nano sponges, are a cheap and mass-producible system of fascinating quantum mechanical and quantum optical properties. For optimized parameters (filling factor, pore size, pore shapes...)[1] and in any given frequency range, always some local pore configurations will act as natural nano antennae and nano cavities[2] with huge Purcell factors $\gtrsim 7000$. Under illumination, electromagnetic energy is transferred from the wavelength scale via the Mie resonance of the whole nano particle ($\sim$200 nm) into hot-spots of tens of nm size or less[3]. The strongly enhanced electromagnetic fields in the hot spots live rather long and dominate the non-linear properties of the sponge, as has been shown via electron emission in Ref. [2]. Thus, tailored gold nanosponges have the potential to be an enabling technology for the exploitation of QED effects in mass-produced systems.

[1] Towards optimal disorder in gold nanosponges for long-lived localized plasmonic modes, F. Schwarz, E. Runge, Ann. Phys. (Berlin) 529(12), 1600234 (2017); [2] Long-lived electron emission reveals localized plasmon modes in disordered nanosponge antennas, G. Hergert et al., Light: S&A 6(10), e17075 (2017); [3] Strong spatial and spectral localization of surface plasmons in individual randomly disordered gold nanosponges, J. Zhong et al., Nano Lett. 18 (8), 4957-4964 (2018)